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APPLICATION FOR UNITED STATES LETTERS PATENT

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

Be it known that I, Ulrich Hege, a citizen of Germany, residing at Am Schwimmbad 8, 85356 Freising, Germany, have invented a new and useful CONTROLLER AND METHOD FOR CONTROLLING THE FLOW OF BREWER'S WORT FROM A CLARIFYING VAT, of which the following is a specification.

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Controller and method for controlling the flow of wort from a lauter tun

The present invention relates to a controller and to a method of the type referred to in the generic clauses of claims 1 and 2.

Such a method for controlling the flow of wort when brewing beer is known e.g. from German Offenlegungsschrift DE 43 24 157 A1. In this method, the actual wort flow is measured and compared with a predetermined desired wort flow. In dependence upon the difference between the actual wort flow and the desired wort flow, the opening of a turning vane and the height of a raking machine are controlled. A wider opening of the control valve will normally lead to an increase in the actual wort flow. A grain bed which has settled on the settling bottom of the lauter tun is broken up by lowering the raking device; this leads to an increase in the actual wort flow as well. In order to achieve the shortest possible lautering time, the desired wort flow is increased in steps with a constant gradient during a trending phase. If, during the trending phase, the desired wort flow increase can be achieved neither by opening the turning vane still further nor by lowering the raking machine because the turning vane is e.g. completely open and because further lowering of the raking machine is not desired, the desired wort flow will be decreased. When the actual wort flow remained constant for a predetermined time or has even increased, the desired wort flow will again be increased in steps with the original gradient.

In addition, the fuzzy logic is known from the prior art. Taking as a basis the theory of fuzzy sets, which was established by Zadeh in 1965, the vague, subjective and equivocal concepts of human thinking can be replicated by algorithms. In contrast to the classic set theory, where each element belongs or does not belong to a specific set, the individual elements of the fuzzy set can also belong to said fuzzy set to a certain degree of membership, which is normally in the interval between 0 and 1. In this case, degree 1 means full membership to the set considered and degree 0 means non-membership. Between these values there is a continuous transition from "being an element" to "not being an element".

Essential elements of the fuzzy logic are the so-called linguistic variables. Their values are not figures, but expressions of informal speech. Since words are less precise than figures, the individual values are represented by fuzzy sets.

When the fuzzy logic is used in a control process, all input variables are first fuzzified. Each input variable defines a linguistic variable on the measurement range of which so-called fuzzy sets are defined. During the fuzzification the degree of membership to the fuzzy sets is determined. By means of a knowledge base, a degree of membership on a set of each output variable is determined on the basis of the fuzzified input variables. The knowledge base is stored in the form of if-then values. The degrees of membership to the output variables are accumulated so as to form an output set. The fuzzy output set is de-fuzzified via the centroid and its point of intersection with the axis of the output variable, whereby a precise value for each output variable is obtained.

Although it is impossible to achieve a reduction of the lautering time by the method described in Offenlegungsschrift DE 43 42 157 A1, the lautering process still remains, also in the case of this method, the wort-production process which requires the longest time and which should therefore be shortened with regard to a further reduction of the brewing period resulting in a higher number of brewing steps per unit time. This should be done without impairing the wort quality. Furthermore, it is desirable that it should, as far as possible, not be necessary to adapt a controller and a method for controlling the flow of wort from a lauter tun to various types of beer, feedstock compositions, compositions of rough-ground material, mash consistencies and lauter tun charges. On the contrary, the controller and the method should adapt automatically to a great variety of types of beer, feedstock compositions etc., by taking into account important parameters.

It is therefore the object of the present invention to provide a controller and a method in the case of which lautering from a lauter tun is accelerated with due regard to the experience of those skilled in the art.

This object is achieved by claims 1 and 2.

Preferred embodiments are the subject matters of the subclaims.

Taking into account the change with time of the position of the control valve is advantageous insofar as the raking machine will react faster, whereby the stroke lengths of the

raking machine will be reduced substantially. This will especially prevent the raking machine from being lowered to a very low level, which would lead to higher turbidity of the wort.

When the turbidity of the outflowing wort is taken into account, preferably in connection with the change with time of the turning vane, this will offer the advantage that the raking machine will travel to constantly varying heights and, especially, that the zigzag knives will not always move along the same tracks.

A smaller water buffer on the grain bed is additionally advantageous insofar as a higher concentration gradient will be obtained, and this will lead to an improved yield.

A lowering of the level in a lauter vessel leads to increase in the differential pressure at the grain bed and thus, advantageously, to an increase in the actual wort flow. By lowering the level in the lauter vessel gradually, a sudden suction effect on the grain bed will be avoided.

A reduction of the sparge water quantity in the case of easy-running brews is advantageous insofar as a future draining time will be reduced.

In the case of poor-running brews, the lautering process can be shortened by prematurely stopping the first wort or a second wort, especially when a raking inhibitor has already been activated.

A forced lowering of the raking machine to a low position, if the raking machine has not moved below a certain level during the first wort, will advantageously lead to a better washing out of the extract.

When the change with time of the position of the turning vane as well as the instantaneous position of the raking machine are taken into account, a premature raising of the actual wort flow will be avoided in an advantageous manner. This would lead to a lowering of the raking machine and thus to an increase in the turbidity of the wort, which would be detected by a turbidity sensor only with a certain delay.

The present invention is additionally advantageous insofar as the lautering time is automatically optimized in accordance with the individual, special characteristics of a brew.

In the following, preferred embodiments of the present invention will be explained in detail making reference to the drawings enclosed, in which:

Fig. 1 shows a schematic representation of a lauter tun provided with a controller according to the present invention,

Fig. 2 shows a lautering process of an easy-running brew,

Fig. 3 shows a lautering process with a first wort which does not run very well towards the end of the process and with a poor-running second wort,

Fig. 4 shows a lautering process with a second wort which runs poorly at the beginning of the process, said second wort running so well towards the end of the process that a smaller amount of sparge water suffices,

Fig. 5 shows a lautering process in which the level in a lauter vessel is not raised completely until the actual wort flow has recovered during the second wort,

Fig. 6 shows a lautering process in which the level in the lauter vessel is slightly lowered in the period in which the first wort does not run very well,

Fig. 7 shows a lautering process in which the first wort runs poorly towards the end of the process and the second wort runs poorly towards the end of the process, and in which sparging was carried out once more during the second wort,

Fig. 8 shows a lautering process in which the raking machine moves to a lower level due to the low turbidity, and

Fig. 9 shows a lautering process in which, due to the high turbidity, the raking machine moves to a level which is not as low as the level in Fig. 8.

Fig. 1 shows a device in which the controller according to the present invention and the method according to the present invention are preferably used. The device comprises a

lauter tun 1, which can be arranged on a support, not shown, so as to provide below the bottom 2 of the lauter tun 1 a space for installing a driving device 3 as well as a lifting and lowering unit 4 for the raking machine 5 arranged within the lauter tun 1. The drive motors for the lifting and lowering unit as well as for the rotary movement of the raking machine are designated by reference symbol M. The raking machine 5 is provided with a drive shaft 6 which is supported such that it is rotatable as well as axially displaceable. The upper end portion 7 of the drive shaft 6 has secured thereto a plurality of horizontal arms 8 which are equally spaced from one another in the circumferential direction and which each support several raking knives 9 for a grain bed settling as a residue on the settling bottom 10 of the lauter tun 1 during the lautering process. The lower end portion 11 of the drive shaft 6 of the raking device is in engagement with the driving device 3 and the lifting and lowering unit 4.

The lauter wort 1 drawn off from the lauter tun 1 flows via an outlet 12 into the collecting vessel 13 and from said collecting vessel 13 into a central tube 14 which is followed by a flowmeter 15 and a control valve 16. The control valve 16 is preferably implemented as a turning vane; it is controlled by the controlling element 18. The flowmeter 15 is used for measuring the actual wort flow of the lauter wort.

The flowmeter 15 and the turbidity sensor 27 are connected to the controller 17, which is, in turn, connected to the controlling element 18, the turning vane 16 and the driving device 3 of the lifting and lowering unit of the raking device 5. In accordance with a further preferred embodiment, the controller 17 additionally controls the lauter pump 26 and the controlling element 22 of the butterfly valve 21. In accordance with another preferred embodiment, the controller 17 controls via the valve 28 the supply of sparge water through the supply line 23. The inflow of sparge water can be determined by the position of said valve 28. In accordance with a further preferred embodiment, the supply line 23 has installed therein a further flowmeter so as to permit a more precise determination of the amount and of the flow of sparge water.

With the aid of the pressure sensors p_1 and p_2, a pressure drop at the grain bed is measured. This pressure drop is referred to as spent grains resistance. The spent grains resistance provides for the lautering process an information value similar to that provided by an actual wort flow measurement through the flowmeter 15. In order to save costs and in view of the fact that the two pressure cells serving a pressure sensors are easily damaged, the

spent grains resistance measured by means of the pressure sensors p_1 and p_2 can either be additionally taken into account in the case of said preferred embodiment or the measurement of said spent grains resistance can be dispensed with. Easy-running brews have a low spent grain resistance, whereas poor-running brews have a high spent grains resistance.

After the control valve 16, the lauter wort 25 flows through a lauter vessel 19, a throttle valve 21, a lauter pump 26 and a turbidity sensor 27. The throttle valve 21 is preferably implemented as a butterfly valve. The controller 17 controls the lauter pump 26 and, via a controlling element 22, the throttle valve 21 so as to control the discharge of lauter wort from the lauter vessel 19. If this discharge can be controlled in a sufficiently precise manner by the lauter pump alone, e.g. by repeatedly switching the lauter pump on and off or by controlling the lauter pump speed, the throttle valve 21 and the controlling element 22 can be dispensed with in accordance with another preferred embodiment. For the purpose of pressure compensation, the lauter vessel 19 is additionally connected to the lauter tun 1 via a balance pipe 24. By controlling the flow of wort from the lauter vessel 19, the level of the wort 20 in the lauter vessel 19 can be controlled independently of the amount flowing in. The difference between the water level in the lauter tun 1 and the lauter wort level in the lauter vessel 19 generates a pressure difference which forces the water in the lauter tun through the grain bed that has settled on the bottom of the lauter tun. It follows that this differential pressure and, consequently, the actual wort flow from the lauter tun 1 can be controlled by varying the level of the lauter wort 20 in the lauter vessel 19.

Line 22 connects the lauter tun 1 to a mash tun.

The device shown in Fig. 1 can be used for executing the method according to the present invention. Fig. 2 to 9 show lautering processes of eight different brews, the first wort being subjected to lautering first, whereupon a second wort follows. The total wort quantity amounts to 350 hl in each case. Normally, the following equations are used for calculating from the process data the amounts of total wort, first wort, second wort and sparge water:

total wort (hl) = S*AF(Pfv*(Pfv*0.004l/0.998))

quantity VM (hl) =: HG / S* 0.64 (hl/dT) / SW – TF*S

quantity second wort (hl) total wort (hl) – quantity VW
(hl)
quantity sparge water (hl): total wort (hl) – HG / S*AF
-S: grist (dT) from process data
-AF: yield factor (% 100) approx. 0.76
-Pfv: predetermined data for full wort concentration (GG%)
-HG: main wort (hl) from process data
-SW: rinsing water (hl) from process data
-TF: specific factor for spent grains volume (hl/dT) approx. 1.80
-AF: sparge water factor (hl/dT) approx. 0.5

The time, in minutes, that has elapsed since the beginning of the lautering process is plotted along the X axes of all diagrams in Fig. 2 to 9. The respective upper diagram shows the actual wort flow 50, the desired wort flow 51 and the height of the raking machine 52 against time. In the respective middle diagrams, the actual wort flow 50, the sparge water quantity 53 and the sparge water flow 54 are plotted in arbitrary units. In the lower diagrams, the lautered wort 55, in hectolitres (hl), is plotted against time, the opening of the control valve 56, in percent, is plotted against time, and the level 57 in the lauter vessel 19, in arbitrary units, is plotted against time. Furthermore, it is indicated after how many hectolitres of lautered wort the trub is added.

In accordance with a preferred embodiment of the present invention, the height of the raking machine is influenced by the turbidity measured by the turbidity sensor 27. The deeper the raking machine cuts into the grain bed, the poorer the filtering effect of the grain bed and the more turbid the lautered wort. Hence, the method according to the present invention and a preferred embodiment of the controller according to the present invention control the height of the raking machine in dependence upon the turbidity of the outflowing wort so that an increase in turbidity will lead to a reduction of the degree to which the raking machine is lowered. A reduction of the raking depth of the grain bed leads, in the final analysis, also to a reduction of the actual wort flow. Since, in the case of an unchanged desired wort flow, a reduced actual wort flow would lead to a lowering of the raking machine, the desired wort flow is reduced as well. In Fig. 8 and 9, the actual wort flow collapses abruptly at points 171 and 182. In Fig. 8 the turbidity is 43 EBC, whereas in Fig. 9 it is 87 EBC. It follows that the raking machine 171 moves down to a lower level at 171 in Fig. 8 than at 182 in Fig. 9.

The use of the fuzzy logic in the method according to the present invention permits input variables, which are effective in opposite directions and which e.g. increase as well as decrease an output variable, to be easily balanced one against the other.

In accordance with a further preferred embodiment, the change with time of the control valve position is additionally evaluated. In this way, the raking machine can react to temporal changes more quickly, whereby the respective stroke lengths will be reduced substantially. Reduced stroke lengths are particularly advantageous insofar as this will especially prevent the raking machine from being lowered to a very low level, which would lead to a increase in the turbidity of the lautered wort. Especially at positions 112, 113, 122, 123, 131, 132, 153 and 154, Fig. 2, 3, 4 and 6 clearly show that the desired wort flow and the actual wort flow correspond well and increase slightly. The raking machine is here lowered all of a sudden because the controlling element 18 rapidly opens the control valve 16.

Fig. 2 and 8 show, in particular at points 114 and 172, that the raking machine repeatedly moves to various heights and that especially the zigzag knives do not move along the same tracks; this is achieved by taking into account both the turbidity as well as the change with time of the control valve position. The grain bed will be cut open more uniformly and therefore also be washed out more uniformly in this way.

In the case of a low spent grains resistance, i.e. in the case of easy-running brews, the water buffer on the grain bed is preferably reduced. Due to the smaller water buffer, a higher concentration gradient will occur when the water is converted into wort upon flowing through the grain bed. A higher concentration gradient has the effect that the grain bed will be washed out more effectively. At points 121, 133, 141 and 152, Fig. 3, 4, 5 and 6 show that, as soon as the actual wort flow has reached or even exceeded the desired wort flow, the sparge water flow is decreased below the actual wort flow, which is referred to as negative offset of the sparge water. This leads to a reduction of the water buffer on the grain bed.

As long as the second wort runs poorly on the other side, the sparge water flow is chosen such that it exceeds the actual wort flow; this contributes to an increase of the water buffer on the grain bed and therefore, via a higher pressure difference, to an increase of the actual

wort flow. The larger water buffer has the effect that the upper part of the grain bed is softened whereby the spent grains resistance will be reduced still further.

In addition, the level of the wort 20 in a lauter vessel is slightly lowered, especially when the water buffer is small, so as to increase the actual wort flow by a higher pressure difference between the lauter tun and the lauter vessel. Especially towards the end of the first wort, the level in the lauter vessel 19 is lowered so as to maintain a sufficient pressure difference between the lauter tun 1 and the lauter vessel 19 and, consequently, an acceptable actual wort flow. A sudden suction effect on the grain bed is avoided by gradually lowering the level in the lauter vessel 19. This is shown in Fig. 6 especially at 151. During a second wort, which follows the first wort, the level in the lauter vessel 19 will not be fully raised until the sparge water supplied has formed a water buffer of sufficient thickness on the grain bed so that the pressure difference between the lauter tun 1 and the lauter vessel 19 will be sufficiently high for raising the actual wort flow approximately to the desired wort flow. This is shown in Fig. 5 at 142.

In the case of easy-running brews, the sparge water quantity resulting from the above formulae is preferably reduced to a certain extent so as to reduce the draining time later on. In Fig. 2, the sparge water quantity amounts to 172 hl and the sparge water flow is less than the actual wort flow during the whole second wort. In Fig. 4, the sparge water quantity amounts to 171 hl. The spent grains resistance decreases here only towards the end of the second wort. The decrease is so substantial that a smaller amount of sparge water suffices. The reverse case is shown in Fig. 3. Since the spent grains resistance was low at the beginning and in the middle of the second wort, i.e. since the brew ran well at the beginning, the sparge water quantity was to be reduced. Since the brew had, however, a high spent grains resistance towards the end of the second wort, sparging was carried out once more (124). The sparge water quantity amounts here to 179 hl. A similar lautering process in which sparging was carried out once more at 161 is shown in Fig. 7. The sparge water quantity amounted here to 180 hl.

In accordance with the present invention, deep cutting is preferably not only caused by the fact that the actual wort flow falls below a certain limit value, but the factors taken into account are preferably the deviation of the actual wort flow from the desired wort flow, the position of the control valve 16, the relative height of the actual wort flow, the height of the

raking machine and the turbidity. The locations at which deep cuts are caused are not shown in Fig. 2 to 9.

According to the present invention also the quantity of the first wort is variable to a certain extent. When e.g. a raking inhibitor, which prevents deep cutting, has already been activated and when only a few hectolitres have to be lautered and the actual wort flow becomes undesirably low, the first wort will be stopped prematurely. Fig. 2 shows a lautering process in which the first wort runs well and in which the whole first wort of e.g. 150 hl is therefore lautered. Fig. 3 shows a lautering process in which the first wort does not run very well towards the end of the process so that the first wort quantity is slightly reduced to e.g. 147 hl. Fig. 7 shows a lautering process in which the first wort runs poorly at the end of the process and in which the first wort quantity is reduced still further to e.g. 143 hl.

Also in the case of easy-running brews, raking at a low position (Fig. 2, 111) is preferably performed so as to improve the washing out of the grain bed during the second wort, if the raking machine has not moved below a certain level during the first wort.

The moment at which the trub is added is preferably determined in dependence upon the spent grains resistance. If the spent grains resistance is high at the beginning of the second wort, the trub will be added later. Fig. 2 shows a lautering process in which the spent grains resistance is low at the beginning of the second wort and in which the trub is therefore already added when 179 hl lauter wort have been lautered. Fig. 5 shows a lautering process in which the spent grains resistance is high at the beginning of the second wort, i.e. in which the second wort runs poorly at the beginning; the trub is therefore not added until 210 hl lauter wort have been lautered.

In addition, the actual wort flow is preferably chosen in dependence upon the change with time of the control valve 16 and the height of the raking machines. The actual wort flow is in particular not increased as long as the raking machine still moves at a low position, so as to avoid an excessive turbidity of the lauter wort. In Fig. 7 the actual wort flow is not increased at 162, although the actual wort flow and the desired wort flow correspond, because the raking machine still moves at a low position and the control valve 16 is in the process of opening quickly.

If the actual wort flow lags behind the desired wort flow, the pressure difference between the lauter tun 1 and the lauter vessel 19 will be increased by feeding CO_2 into the lauter tun in accordance with another preferred embodiment. As far as the actual flow is concerned, a feeding of CO_2 produces an effect similar to that of a thicker water buffer caused by an increased inflow of sparge water or a lowering of the level in the lauter vessel 19. When CO_2 is fed into the lauter tun, the balance pipe is preferably closed so as to prevent pressure compensation with the lauter vessel 19.

The controller according to the present invention and the method according to the present invention use preferably nine input variables, viz. the difference between the desired wort flow and the actual wort flow, the actual wort flow, the change with time of the control valve position, the control valve position, the lautered quantity, the turbidity of the lauter wort, the sparge water quantity, the height of the raking machine, and a Boolean variable which indicates whether the raking machine has once been moved to a low position during the first wort. The controller according to the present invention and the method according to the present invention produce eight output values, viz. the inflow of sparge water (hl/h), the desired wort flow, the height of the raking machine, the fine adjustment of the height of the raking machine, the level in the lauter vessel, a trigger for the termination of the first wort, a trigger for the addition of trub and a trigger for a deep cut.

The method according to the present invention is preferably implemented by means of a fuzzy controller which operates according to the max-prod interference mechanism and which applies the next-centroid method for de-fuzzification. In addition, an old value will be maintained, if no rule is active.

Since outputs are fed back to inputs in accordance with the method according to the present invention, the output values of the controller are kept constant e.g. for two minutes at the beginning of the lautering process so as to prevent wild transients when the lautering process begins. In accordance with other preferred embodiments, various outputs of the controller begin to vary the constant values according to the control method after different periods of time. For example, one minute after the beginning of the lautering process a control of the actual wort flow is started, in which the actual wort flow is controlled by means of the control valve 16 such that it corresponds to desired wort flow, whereas the height of

the raking machine is not changed until another four minutes have elapsed. After five minutes more, the level in the lauter vessel 19 is included in the control as well.